CONSERVATION INNOVATION GRANTS

Final Report

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Project Director: Dana M Kirk	
Contact Information:	**Phone Number:** 517.432.6530 **E-Mail:** kirkdana@anr.msu.edu
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Project Background

Self-generated renewable fuels can be a valuable asset to an agricultural operation. For many farms, energy represents a large fraction of their variable costs of production. Dairy operations, in particular, are large consumers of energy for lighting, milk chilling, pasteurization and equipment sanitation. To mitigate the risk of over-reliance on fossil-fuel energy sources agricultural operations are seeking alternative energy solutions to meet on-farm energy needs and to improve the overall environmental quality on the farm.

In this document, we will describe a hybrid on-farm energy system that can produce multiple types of bioenergy from both oilseed crops (biodiesel) and agricultural waste (biogas). On-farm generation of energy allows farmers to decrease the amount of fossil fuels purchased for farm use, thereby improving their economic sustainability. In addition, the proposed system offers substantial environmental improvements via improved on-farm water quality and enhanced crop management on the farm.

This is an innovative strategy for on-farm bioenergy production, yet has less technical risk than other new energy generation approaches since it is based on the proven technologies of biodiesel-from-oilseeds and biogas from anaerobic digestion. The especially positive (and innovative) feature of this project is the enhanced energy production efficiency achieved by combining two parallel energy production processes. Enhanced efficiency is critical if the farmer is to cost-effectively replace purchased fossil-fuels that are used on-farm.

Technical Background

Oilseed crops are known for high oil content in their seeds. Oil can be extracted using traditional extruders and then converted into biodiesel using mature biodiesel processing technologies. For greatest efficiency, a solvent-based transesterification process is often used to convert oilseed-based oils into ASTM-D6751-compliant biodiesel. However, the transesterification process is only feasible at large-scale, and is further expensive and complex. For these reasons, a smaller farm operation will instead use mechanical presses to extract oil from the oil seeds and produce biodiesel using small scale transesterification equipment. While the resulting biodiesel is not ASTM-D6751 compliant and less efficiently produced, it is nonetheless an excellent drop-in biofuel for farm-based applications.

Challenges with small scale production include poor extraction efficiency, resulting in meal with higher oil content, use of the meal given the relatively small quantity, and disposal/use of the glycerin. It is acknowledged that meal has good market value for animal feed, however, animal feed buyers want a product that is in large quantity and consistent in nutritive value, and the market for oilseed meal is mature and active, limiting opportunities for small scale producers. The challenges are significant, but can be mitigated by adopting an approach that maximizes the production efficiency at every step, such as integration of biodiesel and anaerobic digestion technologies.

Our approach is a Hybrid Biodiesel-Biogas (Hybrid) system that takes advantage of the fact that a significant fraction of the oilseed oil remains in the meal after crushing, and therefore represents a potential benefit to the farmer. A bio-crop such as canola seed has approximately 42-43% oil before processing. The extraction efficiencies for expeller-press systems can be highly variable. Less expensive units are as low as 45-50% efficient, meaning the post-expeller meal contains around 18-20% oil. The key to our approach is to use biodiesel by-products effectively, particularly the use of oilseed meal and glycerin. This oilseed meal is an excellent co-feedstock for an anaerobic digester, and will increase biogas production when mixed with other feedstocks. Our initial calculations show that biogas production can increase significantly.

Project Objectives

The purpose of the proposed CIG effort is to demonstrate an effective bioenergy production system. Our goal is to show that, by maximizing efficiency of the overall production process, we can ultimately achieve cost-competitiveness of biodiesel for on-farm uses. This approach is innovative in the sense that it takes advantage of the synergy between biodiesel and biogas production to maximize the overall production efficiency of biofuels.

Objective 1: Pilot scale testing

For pilot scale testing, MSU ADREC staff used the MSU Extension trailer mounted, demonstration scale on-farm biodiesel system to crush canola seed to produce the oil necessary to generate biodiesel for demonstrations. Meal from the crushing and glycerin from the biodiesel production were used in the Hybrid project as feedstock for anaerobic digestion demonstration trials. Throughout the project approximately 12,000 lb. of canola were processed, yielding approximately 2,900 lb. of bio-oil for conversion into 2,600 lb. (350 gal.) of biodiesel.

The resulting meal (9,100 lb.) and glycerin (300 lb.) were used as anaerobic digester feedstock in four 300 liter pilot scale digesters. During the pilot demonstrations, the digesters were operated with 3 feedstock variations:

1. Liquid dairy manure only (dairy manure)
2. Liquid dairy manure plus biodiesel byproducts
3. Liquid dairy manure plus biodiesel glycerin (glycerin)

For the feedstock variations with “dairy manure plus”, four addition levels were tested; 0.25%, 0.5%, 1.0%, and 2.0% by mass. The ratio of biodiesel byproducts was 95% meal and 5%

glycerin.

The non-manure feedstock additions were based on findings during the early stages of the project when an Excel model was developed, which compared land base requirements for oilseed production to the anaerobic digestion feedstock blend levels of potential interest to producers. Michigan like many States, allow blending of non-manure feedstocks in anaerobic digester up to 20% based on mass, with no modifications to environmental regulations or permits. Originally, we intended to demonstrate blends containing 5% to 20% biodiesel byproducts. However, once we began to look at the land base required to achieve those blend levels we felt that demonstrating those blend levels would not be appropriate for most farms. Looking at a 100 cow dairy, approximately 12 acres of canola will allow for a 0.25% blend, while over 1,200 acres of canola is needed for a 20% blend. Based on this finding, we have revised the anaerobic digestion demonstration plans to focus on blends containing 0.25% to 1.0% biodiesel byproducts.

For all pilot digester demonstrations the hydraulic retention time (HRT) was 20 days, a normal rate for North America. Also, the digesters were operated in the mesophilic temperature range.

Table 1 compares the results of demonstrations using the 3 different feedstock blends. The baseline of dairy manure achieved an average biogas production of 78 mL per day. With both the biodiesel byproducts and glycerin feedstock additions, biogas quantity and quality improved significantly. A basic addition of 0.25% by mass resulted in a doubling of biogas production for both feedstock additions compared to manure only. Increasing the additions to 1% yielded three times the biogas production compared to manure. Adding the mixture of biodiesel byproducts resulted in a slight increase in methane yield. However, the addition of only glycerin resulting from biodiesel production increased the methane concentration between 8 and 13%.

Table 1: Comparison Biogas Production from Biodiesel Products and Blends

Feedstock Blend	Daily Average Biogas Production per HRT (mL/d)	Cumulative Biogas Production per HRT (mL)	Methane Concentration (%)
Dairy manure only	78	994	58.8
0.25% Biodiesel Byproducts + Dairy manure	156	2,569	60.5
0.5% Biodiesel Byproducts + Dairy manure	200	3,297	59.9
1% Biodiesel Byproducts + Dairy manure	240	3,941	62.7
2% Biodiesel Byproducts + Dairy manure	423	7,007	63.5
0.25% Glycerin + Dairy manure	165	2,793	66.6
0.5% Glycerin + Dairy manure	190	3,316	67.5
1% Glycerin + Dairy manure	240	3,937	69.0
2% Glycerin + Dairy manure	337	5,509	71.1

The technical papers summarizing the findings contained more detailed analysis of the performance benefits of co-digesting dairy manure and biodiesel byproducts. In addition, the Excel based model of the small farm hybrid biopower is available on request from MSU or Quantalux.

Objective 2: Farm-based demonstrations
Numerous on-farm/local demonstrations were held around Michigan throughout the grant.

1. MSU Extension modified their trailer mounted, demonstration scale on-farm biodiesel system. Modifications included installation of a second seed crusher as well as a plate and frame oil press/filter. The second crusher provided the throughput capacity required for the Hybrid project. In addition, it enhances the demonstration and outreach capacity, essential doubling the capacity for hands-on seed crushing training activities. The plate and frame oil press/filter eliminated an antiquated oil centrifuge. Educators involved with the Hybrid project felt strongly that the plate and frame equipment is more representative of commercial equipment used in small scale production systems.

2. In 2013, the Extension team conducted several biodiesel training session using the new equipment. All told, four biodiesel demonstrations were carried out by bioenergy educators Dennis Pennington, Charles Gould, and Mark Seamon. Approximately 250 attendees participated in the production of biodiesel from raw oilseed and learned how biodiesel can be blended with petroleum diesel for use in farm equipment and off-road vehicles. The demonstrations were carried-out using the trailer mounted, mobile processing unit.

   This project was intended to increase the number of farmers in the Midwest who make their own biodiesel. Measurements of the project's impact were conducted when a full presentation and hands-on education took place.

   Written evaluations of the demonstrations showed the following:
   - 94% increased or considerably increased their knowledge as a result of the demonstration
   - 79% agreed or strongly agreed to being confident in making decisions based on the subject matter of the demonstration
   - 29% agreed or strongly agreed to thinking of making a change in farm practices as a result of the demonstration
   - 43% plan to produce a bioenergy crop on their farm
   - 53% are very likely or somewhat likely to invest in equipment to produce biodiesel
   - 80% plan to use biodiesel on their farm in the future
   - The most common factor (81%) in determining whether or not to produce biodiesel on farm was economics of production

   The success of this biodiesel demonstration program was directly related to its innovative use of mobile equipment that gave participants a hands-on opportunity to understand the process and equipment needs within small groups of interested people.

3. In August of 2013, MSU ADREC and MSU Extension teamed to host a Waste to Resource Field Day. The field day was attended by approximately 100 individuals who were introduced to MSU demonstration and commercial activities related to anaerobic digestion, biodiesel production and compost. Demonstration of the Hybrid system was a focal point during the field day.

4. MSU Extension partners held a bioenergy and energy conservation field day for August 28, 2014. The field day highlighted on-farm biodiesel production, ongoing demonstration activities at the MSU digester systems and the feasibility of producing oilseed crops for on-farm biodiesel production. In addition, the tour will stop at two energy conservation sites to provide participants a balanced understanding of energy related issues facing agriculture. The tour involved 51 participants.

5. In late 2014, the on-farm biodiesel pilot system was moved at the Lenawee County Tech Center to demonstration biodiesel production. The system also provided local farmers and citizens opportunities to gain hands on training with small scale biodiesel production. The Tech Center has an affiliated FFA Chapter which also used the system as part of their STEM curriculum.

6. In 2015, a team of students involved with the Springport High School FFA and STEM program used the pilot digester to demonstrate co-digestion of dairy manure to increase biogas potential. The team ran a series of demonstration trials, collected data and prepared a report summarizing the findings. In April, the team won the State FFA science contest on the strength of their project and went on to compete at the National Conference.

Objective 3: Information dissemination
Outcomes of the project have been summarized in a peer-reviewed paper that is currently under review. The paper is focused on the economic synergies of the combined system and identifies opportunities and challenges associated with the Hybrid system. In addition to the paper, several national/international presentations were developed and given including:

- Biogas potential of dairy manure and biodiesel byproduct blends, an investigation into the feasibility of the hybrid biorefinery concept. July 2014. ASABE International Annual Meeting. Montreal, Canada.

- Hybrid Biorefinery – Biodiesel and Biogas Production Synergies. October 2013. Biocycle Conference. Columbus, OH.

- Valuing Feedstocks for Anaerobic Digestion – Balancing Energy Potential and Nutrient Content. March 2013. Waste to Worth Conference. Denver, CO.

In addition a series off YouTube style videos have been developed and published to educate farmers and citizens about the opportunities of using biodiesel, anaerobic digestion and the synergies of integrating the technologies. The videos are posted on the two MSU sites focused on bioenergy and anaerobic digestion.

http://bioenergy.msu.edu/hybrid
http://www.egr.msu.edu/bae/adrec/usda-cig

Conclusions

Development and application of biodiesel and anaerobic digestion systems are currently struggling to gain a footing due to a number of factors ranging from low conventional fuel market values to a lack of National policy related to renewable energy. That being said, the integration of biodiesel and anaerobic digestion does provide clear benefits to both the technologies. Based on the Excel model developed during the project, a small 100 cow dairy farm would require approximately 12 acres of canola to produce enough biodiesel to satisfy annual fuel consumption. At this level of biodiesel production, the co-feed percent of glycerin would be approximately 0.25%. Even this small addition of glycerin or canola meal plus glycerin, 0.25% by mass, can double biogas production from a dairy manure based anaerobic digester. The opportunity to use biodiesel meal and glycerin from small scale producers in the digester eliminates challenges with byproduct management, improves the efficiency of the process and creates an overall green fuel source. The benefits to the digester, of even small additions of glycerin, are profound in terms of biogas quantity and quality. However, given the current market status, widespread technology deployment is not currently feasible.